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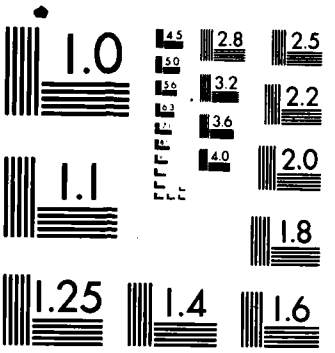

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The work carried out during the 1984/85 contract year is divided into two parts. First, three classes of component dependency models have been successfully incorporated into the Markov Monte Carlo formulation: standby systems, shared load systems and shared repair crews. These models have been implemented in a computer code and used for the analysis of a number of complex systems. Second, the investigation of the Monte Carlo simulation of time-dependent failure was begun. Two different sampling techniques were formulated, and evaluation is continuing into the 1985/86 contract period.

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In studying Markov Monte Carlo methods we are working toward the development of simulation methods capable of performing reliability analysis of complex fault-tolerant systems. In this work component dependencies require the use of Markov or semi-Markov models that would require the solution of sets of millions of coupled differential equations if deterministic numerical methods were to be employed. Markov Monte Carlo simulation, however, circumvents the problems inherent in deterministic modeling and has the long term potential for providing computer-aided engineering tools for the allocation of redundance, for the optimization of parts replacement and maintenance policies and for other reliability related tasks.

Before the 1984/85 contract perod, the Lagrangian framework in which the Markov simulation is carried out was shown to be inherently more efficient than traditional direct Monte Carlo methods. In addition. we have introduced two importance sampling schemes, forced transitions and failure biasing, that further improve computational efficiency by three or more orders of magnitude. These variance reduction techniques have permitted the study of systems with exceedingly small failure probabilities. Finally, techniques were developed for the study of the propagation of failure rate data uncertainty and for determining at what point the variance of the Monte Carlo simulation is dominated by data uncertainty rather than the limited number of independent trials.

During the 1985/86 contract period research has been concentrated in two areas. First, we have developed and implemented quite general component dependency models that include standby systems, load sharing and shared repair crews. Moreover, the stsndby systems include switching failures and failures of the backup systems as well as component repair. These dependency models have been formulated in such a manner that they are compatible with the variance reduction techniques, and they have been applied to the reliability and availability of large systems. Papers based on this work have recently appeared; they are listed below.

During the second half of the 1984/85 contract period efforts have been concentrated on expanding the analysis to semi-Markov methods capable of treating the time-dependent failure rates that are required if either wear effects of preventive maintenance are to be taken into account. Two candidates, one a from of rejection sampling, and the other which we refer to as failure mode sampling, are currently being evaluated. This work, which extends into the 1985/86 contract year, also addresses the interactions between time-dependent failure rate sampling and the aforementioned variance fixed time intervals on the simulation. With these techniques the modeling of preventive maintanance and parts replacement will be investigated, and the study of systems with mixed age and batch parts replacement will be undertaken. It is anticipated that a paper based on this work will be submitted to Reliability Engineering during the 1985/85 contract year.

The AFOSR contract provided partial support for two graduate students at Northwestern University: Laural Olvey and Ilhan Dilber. Also involved in the work, but not supported by AFOSR money, was Zhuguo Tu, a visiting scholar from The People's Republic of China.

Publications based entirely or in part on AFOSR sponsored research:

(1) E. E. Lewis and L. Olvey, "Monte Carlo Unavailability Analysis," Trans. Am. Nucl. Soc. 47, 329 (1984).

(2) Z. Tu and E. E. Lewis, "Component Dependency Modeling in Markov Monte Carlo Calculations," Trans. Am. Nucl. Soc. 49, 287 (1985).

(3) E. E. Lewis and A. Tu, Monte Carlo Simulation of Reliability Problems," Proc. ASME Pressure Vessel & Piping Conf., PVP-Vol. 98-5, New Orleans, June 24-26, 1985.

(4) Z. Tu and E. E. Lewis, "Component Dependency Models in Markov Monte Carlo Reliability Analysis," Reliability Engineering 13, 45-61 (1985).

Presentations by E. E. Lewis based on AFOSR sponsored research:

"Monte Carlo Unavailability Analysis," Am. Nucl. Soc. National Meeting, Washington DC, Nov. 15, 1984.

"Markov Monte Carlo Reliability Analysis," AFOSR Reliability Workshop, Luray, VA, May 30, 1985.

"Component Dependency Modeling in Markov Monte Carlo Calculations," Am. Nucl. Soc. National Meeting, Boston, MA, June 12, 1985.

"Monte Carlo Simulation of Reliability Problems," ASME Pressure Vessel & Piping Conf., New Orleans, June 24, 1985.

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